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The Relationship Between
Subjective and Objective
Measures of Sleepiness

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Summary

The purpose of the present study was to examine the relationship among the Multiple Sleep Latency Test (MSLT), lapses during a tapping test, a visual analog scale (VAS), and the Stanford Sleepiness Scale (SSS). Subjects were 80 male adult nonsmokers (age 20.3 ± 2.7 years). The MSLT, SSS, and VAS were obtained at two-hour intervals beginning at 0700 h and ending at 1700 h. On the MSLT, sleep latency was measured from lights out to first spindle, K-complex or rapid-eye-movement (REM) period. The tapping task (lapses) was administered each day at 0600 h, 1000 h, and 1400 h. A lapse was a 3 seconds (s) or greater pause between taps. Correlations between objective (MSLT and lapses) and subjective (VAS and SSS) measures were significant at 0600 h, but became nonsignificant as the day progressed. Correlations of objective and subjective measures from scores summed over both days were not significant. The two objective measures were significantly correlated throughout the day and over days as were the subjective measures. This study reaffirms the importance of time of day in sleepiness, and suggests that subjective and objective measures cannot be used interchangeably and may measure different aspects of sleepiness.

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Introduction

Both subjective and objective measures are currently used to assess sleepiness. The most frequently used subjective measure is the Stanford sleepiness scale (SSS) (1) followed by the Visual Analog Scale (VAS) (2). The Multiple Sleep Latency Test (MSLT) is the standard objective measure of sleep tendency (3,4). Less frequently used is the subjective Thayer activation-deactivation subscale check list (5) and the objective measure of behavioral lapses during performance tests (6,7). The Maintenance of Wakefulness Test (MWT) (8) is also used as a measure of sleepiness on the assumption that sleepy people have difficulty staying awake. The MWT has some similarity to lapses in that the subject is asked to stay awake during a task, usually a tapping test. Sleep researchers have used one or more of the above measures of sleepiness on the assumption they were giving comparable data on a physiological state. This assumption was based on the belief that sleepiness was a unitary state that could be measured by either subjective or objective measures. This belief was supported by studies of sleep-deprived subjects by the Stanford group in which they reported high relationships between the MSLT and SSS (9-12).

However, more recent Stanford studies have found no significant relationship between the SSS measures and the MSLT in insomniacs and non-insomniacs (13). Dement et al (14) also found no significant correlation between MSLT and SSS in apneic patients. Clodore et al (15) found no significant relationship between the Thayer activation-deactivation scale and MSLT in a study of diurnal variations in sleepiness. Further, they observed that, paradoxically, alertness and sleep propensity were high around the same time of day.

Though correlations were not reported, Roth et al (16), Sugerman et al (17), and Borbely (18) have all reported differences between the SSS and MSLT in clinical (apneics and insomniacs) (16, 17) and normal subjects (18).

Lapses in performance, usually a reflection of microsleeps, though frequently measured in early sleep deprivation studies (6,19), have not been frequently used as a measure of sleepiness in sleep studies. To our knowledge, no one has related lapses to the current commonly used measures of sleepiness.

The present study was part of a larger 3-day, 2-night research project which utilized a double-blind, parallel groups-design to examine the effects

of benzodiazepines and caffeine on nocturnal and daytime sleepiness, arousal levels, performance, and mood. Five cognitive tests plus the profile of mood states (POMS) were administered 9 times during the 3 days; a training session the first day and four batteries on the 2 following days. Subjects were randomly assigned to one of eight treatment groups (see Table 1). Results from the larger study will be reported elsewhere. In this study, the relationship among the sleepiness measures was examined at different times of day over 2 days.

TABLE 1.
Treatment Groups

<u>Group</u>	<u>Evening</u>	<u>Following Morning</u>
1.	Placebo	Placebo
2.	Placebo	Caffeine (250 mg)
3.	.25 mg Triazolam	Placebo
4.	.5 mg Triazolam	Placebo
5.	.5 mg Triazolam	Caffeine (250 mg)
6.	15 mg Flurazepam	Placebo
7.	30 mg Flurazepam	Placebo
8.	30 mg Flurazepam	Caffeine (250 mg)

METHODS

Subjects

Subjects were 80 male Naval corpsmen, mean age 20.3 ± 2.74 years, from the San Diego Naval School of Health Sciences, San Diego, California. The Naval Health Research Center (NHRC) sleep and medical questionnaire was used to screen subjects for good health, normal sleep, nonsmokers, consumption of not more than 3 cups of caffeinated beverage a day, and current abstinence from sedative medications. Subjects arrived at 1300 h on the day of the first treatment night for briefing and practice sessions. Each participant read a description of the research project, signed a privacy act statement,

and completed a consent form. Experimenters tested all subjects for consumption of drugs or alcohol within 48 hours through a urine analysis at the Navy Drug Screening Laboratory, and a breath alcohol test with a Federal Signal Intoxilyzer 5000. These tests were always negative. When not being recorded or tested, subjects were allowed to read, watch TV, or listen to the radio, but were not allowed to sleep or stay in bed. Bedtime was 2200-0530 h. After all data were collected, subjects were debriefed.

Subjects were run in pairs over two days with both participants receiving the same treatment. Three pairs were dropped and replaced by three new pairs. Two subjects, one from each of two pairs, were released early due to non-study related illness. Another pair was dropped from the study because they ate larger than allowed breakfasts.

Treatments:

The 80 subjects were randomly assigned in equal numbers to 1 of 8 groups in a parallel-group, double-blind design. Each group received similar capsules at 2145 h and 0515 h on two nights. The groups differed with respect to treatment (whether they received flurazepam, triazolam, or placebo) by hypnotic dose level, (flurazepam 15, 30 mg, or triazolam 0.25, 0.50 mg), and as to whether they received caffeine or placebo in the morning. The 8 groups are listed in Table 1.

MSLT/VAS/SSS Procedure

Subjects were trained on all sleepiness measures following the completion of preliminary screening procedures and consent forms. The MSLT training session usually occurred between 1600-1630 h. An eight-channel Beckman Polygraph was used during the MSLTs to record EOG, EKG, and EEG. EEG was recorded from central (C3-C4) and occipital (O1-O2) scalp electrodes, with opposite ear (A1-A2) for reference. Six MSLTs were administered on each of the two treatment days, one every 2 hours beginning at 0700 h and ending at 1700 h. The subject was asked to take his temperature three times, and to complete the SSS and the VAS before each MSLT. On the SSS, possible responses to the question, "Which choice best describes how you feel right now?" ranged from (1) 'Alert, Wide Awake' to (7) 'Almost Asleep.' The VAS asks subjects, "How sleepy do you feel?" and to draw a mark between 'Very Little' on the left end of a 100 mm line and 'Very Much' at the right end.

Following completion of the SSS and VAS, subjects were instructed to go to sleep, and the lights were turned out. Technicians were instructed to awaken subjects 1 minute (min) after onset of stage 2 or REM sleep. Subjects then took their temperatures and completed the two subjective sleepiness scales again. If subjects failed to fall asleep within 20 minutes, they were asked to get out of bed and complete the subjective measures. The post MSLT data are not included in this study.

Sleep latency (SL) to stage 2 was scored blind by the first author. To examine the difference between using stage 2 or stage 1 for scoring sleep onset, the SL to stage 2 was compared with the Stanford criteria of 3 consecutive epochs of stage 1 in 20 subjects. The mean difference between the 2 measures was 1.3 ± 1.79 min. Most (145/260) differed less than one min, and in 83 instances, Stages 1 and 2 criteria were met on the same page. The three largest discrepancies were 14, 9, and 6 min. In this sample of young adult sleepers, the 2 sleep-onset criteria yielded very similar results.

Lapses

The subject was instructed to sit upright in bed, relax but stay awake, and to tap at a comfortable rate on a key beside his bed for 10 min, five min with eyes closed (EC) and five min with eyes open (EO). The task was administered each day at 0600, 1000, and 1400 h. Technicians were instructed to remind the subject to keep tapping after a 5-10 s failure to respond. A lapse was scored when the time between taps was longer than 3 s. Both the number of lapses and duration of lapses were scored. Correlation between the number of lapses and the total time occupied by lapses was [$r(80) = .90$, $p < 0.001$]. The number of lapses was used in further analyses rather than the total time occupied by lapses because it was less influenced by variability between technicians as to how diligently they reminded subjects to keep tapping.

RESULTS

Lapses

The EC-EO correlation for number of lapses was [$r(80) = .84$, $p < 0.001$] on Day 1 and [$r(80) = .84$, $p < 0.001$] on Day 2. EO and EC were combined because of the high correlations even though the number of lapses during EO were significantly higher than EC over both days [$t(79) = -3.07$, $p = 0.003$]. Subjects may have become drowsier or bored in the EO period as it always

followed EC. A day by time repeated measures Analysis of Variance (ANOVA) revealed a significantly higher mean number of lapses on Day 2 [$F(1,73) = 11.31, p = 0.001$]. More lapses occurred on trial 1 (0600 h) for both days (see Table 2).

TABLE 2.

Means and Standard Deviations (SD) of Four Sleepiness Measures

	MSLT Mean (SD)	VAS Mean (SD)	SSS Mean (SD)	Lapses * Mean (SD)
<u>Day 1</u>				
0700h	8.9 (6.5)	55.3 (23.6)	3.4 (1.3)	5.1 (5.9)
0900h	8.3 (5.3)	30.3 (21.8)	2.1 (1.1)	4.0 (5.0)
1100h	8.0 (5.3)	32.9 (23.1)	2.3 (1.0)	
1300h	7.6 (5.0)	27.3 (22.0)	2.1 (.9)	4.5 (5.7)
1500h	8.3 (5.2)	36.1 (25.8)	2.3 (1.1)	
1700h	9.3 (6.0)	25.1 (21.6)	1.8 (.9)	
Day 1	8.4 (4.8)	34.5 (16.9)	2.3 (.8)	4.5 (4.4)
<u>Day 2</u>				
0700h	8.1 (5.4)	60.2 (26.0)	3.7 (1.4)	8.0 (7.0)
0900h	8.1 (5.3)	33.4 (23.1)	2.3 (.9)	4.9 (6.1)
1100h	8.5 (4.6)	29.5 (22.3)	2.1 (.9)	
1300h	7.9 (5.0)	26.2 (19.6)	1.8 (.9)	4.4 (5.6)
1500h	8.9 (6.0)	31.1 (21.4)	2.0 (1.0)	
1700h	10.5 (5.9)	24.8 (20.3)	1.8 (.8)	
Day 2	8.7 (4.3)	34.2 (16.4)	2.3 (.7)	5.7 (5.2)

MSLT = Multiple Sleep Latency Test; VAS = Visual Analog Sleepiness Scale;
SSS = Stanford Sleepiness Scale

* Lapses were recorded at 0600, 1000, and 1400 h on both days.

MSLT, VAS and SSS

The mean pretreatment MSLTs (10.1 min) for all subjects was similar to the mean of 11.1 min reported by Levine et al (20) for a group of young adults, and the mean of 9.9 min they found in 76 college students. The means and standard deviations during the treatment period for the MSLT, VAS, and SSS were similar on days 1 and 2 (see Table 2). Subjects were most sleepy, as measured by VAS and SSS, at 0700 h and SL was longest at 1700 h. There was an early afternoon mild decrease in SL. Subjects' SL decreased at 1300 h on the MSLT, but on the subjective measures, there was a shift toward less alertness at 1500 h.

Relationship Among Sleep Measures

Pearson correlation coefficients were first obtained using a single score for each subject on each sleep measure, the average of his scores over all trials on both days, 12 scores for the MSLT, VAS, and SSS, and 6 scores for lapses. The correlation between lapses and MSLT was $r(79) = .51$, $P = 0.001$, and that between SSS and VAS was $r(80) = .52$, $p = 0.001$. The correlations between the objective and subjective measures did not approach significance; the largest correlation was .18 between lapses and VAS.

Subsequently, the objective-subjective correlation pattern was examined at different times of day over the two days of testing. Since the lapses were not given as frequently nor at the same time as the other 3 measures, some averaging of the MSLT, VAS and SSS scores was done. Data for the lapses at 0600 h was correlated with data from the SSS, VAS, and MSLT at 0700 h; lapses at 1000 h were correlated with the average of the MSLT, VAS, and SSS data from 0900 and 1100 h, and lapses at 1400 h were related to the average of the MSLT, VAS, and SSS scores data from the 1300 and 1500 h trials.

The 3 correlations for each day are presented in Table 3. Inspection of the data indicates a clear time of day effect. At 0600 h, all measures were significantly correlated on day 1; on day 2, all were significantly correlated except lapses and SSS. Lapses and VAS were still significantly correlated at 1000 h on both days, but no other subjective and objective correlations were significant. VAS and SSS were significantly correlated at all time periods as were MSLT and lapses.

Relevance of Treatment

To examine whether the above results were specific for our treatment groups, or could be viewed as representative of an untreated sample, we first examined the correlations among the 4 measures using pretreatment data obtained at approximately 1600 h. These results are also listed in Table 3. Though the correlations (especially between MSLT and lapses) were lower, probably due to time of day and reduced intersubject variability, the pattern seen during treatment was present pretreatment.

Table 3.
Correlations Among Four Sleepiness Measures

Time	MSLT- Lapses	MSLT- SSS	MSLT- VAS	Lapses- SSS	Lapses- VAS	SSS- VAS
<u>Day 1</u>						
0600	-.51**	-.31**	-.34**	.25*	.34**	.63**
1000	-.31**	-.10	-.14	.19	.28*	.62**
1400	-.46**	-.09	-.12	-.04	-.01	.56**
<u>Day 2</u>						
0600	-.32**	-.31**	-.31**	.12	.28*	.72**
1000	-.42**	.02	-.07	.09	.31**	.51**
1400	-.40**	.13	.14	.03	.03	.52**
<u>Pretreatment</u>						
1600	-.22*	-.10	-.08	.11	.08	.48**

* $p < .05$; ** $p < .01$.

To further examine possible treatment effect, we obtained the correlation between MSLT and SSS for each of the 8 groups using a single averaged sleep score for each subject. None of these correlations were significant. Inspection of the regression lines revealed that the slope was generally negative for groups receiving a hypnotic or a placebo in the morning, and positive for the 3 groups who received 250 mg caffeine in the morning. To further examine this difference in slope, we obtained the correlation, again between SSS and MSLT, for the 30 subjects receiving caffeine and the 40 subjects receiving hypnotics at night but no morning caffeine. For both groups, the correlation, again using a single score averaged over all trials, was nonsignificant. Time of day effect was investigated by obtaining the MSLT-SSS correlation for each trial with scores combined over days. None of the correlations for the caffeine subjects approached significance. For the hypnotic subjects, the correlation was significant for early morning trial 1, $r = -0.32$, $p = 0.05$. This correlation is similar to those reported for that time period for the 80 subjects (see Table 2). The MSLT-SSS correlation for the placebo group was similar to the hypnotic groups. The correlation using an averaged score for each subject was $r = -0.53$, $p = 0.11$, $N = 10$, but the correlation for the 0700 h trial was -0.85 , $p = 0.001$. By 0900 h, the correlation had fallen to -0.53 , $p = 0.09$, and was $+0.03$ at 1100 h.

DISCUSSION

In this sample of 80 young adult good sleepers examined over 2 days in a study designed to ensure a wide range in daytime alertness, we found no overall significant relationship between objective and subjective measures of sleepiness. Our 2 objective measures, MSLT and lapses, were consistently significantly correlated as were the 2 subjective measures, SSS and VAS. Only in the early morning were the subjective and objective measures significantly correlated. For the total sample, these correlations were modest, in the low .30s, and lapses and SSS were significantly correlated only on trial 1, day 1. Except for lapses and VAS, the significant correlations between objective and subjective measures had disappeared by 1000 h. By 1400 h, lapses and VAS were no longer significantly correlated. Though the N of the placebo group was only 10, at 0700 h the correlation between MSLT and SSS in that group was -0.85 ($p = 0.001$) falling to $+0.03$ by 1100 h. It is of interest that caffeine effectively abolished the negative relationship

between MSLT and SSS, and that the regression line had an insignificant positive slope (21,22). But this treatment effect of caffeine was a significant factor only in the early morning trial. The negative relationship between sleep measures in the hypnotic group, though somewhat alleviated in the early morning trial, was similar to that for placebo.

Borbely et al (18) also reported that the correlation between MSLT and a subjective estimate of tiredness was significant in the morning, but as the day progressed, there was an increasing difference between the objective and subjective measures of sleep propensity. There was also a difference in the time of the afternoon dip in alertness. This dip occurred at 1300 h on the MSLT, but on the subjective variables, the dip occurred at 1500 h. A similar difference between subjective and objective measures in time of occurrence in the afternoon dip has been reported by Clodore et al (1986).

When there has been a discrepancy between MSLT and SSS, the discrepancy has usually been a subjective estimate of being alert on the SSS, while going to sleep quickly on the MSLT. Various explanations for this discrepancy have been proposed. Dement et al (14) said their sleep apneic patients had been sleepy for such a long period of time, they no longer had a realistic reference for judging alertness. Roth et al (16) also found that the apneic patients rated themselves as more alert than controls on the SSS, but on the MSLT their SL was significantly shorter than nonapneic controls. They interpreted their results as reflecting the sensitivity of the MSLT which was not subject to motivational factors or the need to deny sleepiness. Seidel et al (1984) also explained their failure to find a significant relationship between MSLT and SSS as due to the difference of motivational factors on the SSS. Carskadon's and Dement's views (22) are similar to those of Seidel et al (13) and Roth et al (16). They prefer to view S on the MSLT as a measure of physiological sleep tendency.

Such reasoning implies that there is a difference between the psychological and the physiological dimensions of sleepiness. For Clodore et al (15), the lack of correlation between subjective, Thayer activation-deactivation scale, and MSLT indicated that the two, "are not fully controlled by the same physiological mechanisms." A full discussion of possible explanations and mechanisms of sleepiness is beyond the scope of this brief paper, and the topic will be explored in a forthcoming paper detailing the correlation, or to be more specific, the lack of correlation

between daytime sleepiness, performance, mood, and nocturnal sleep. A special issue of Sleep (Supplement 2, 1982) dealt with current perspectives on daytime sleepiness. But two issues are briefly noted here. First, is there more than one type of sleepiness, and second, is sleepiness a state or trait phenomenon. Broughton (23) has addressed the first question and believes that "there are indeed multiple different states of sleepiness." Broughton (23) cites the sleepiness induced by sleep deprivation and the daytime sleepiness that reflect different types of physiological dysfunction in support of his position. Perhaps there is a third type, -- high sleep propensity, as measured by the MSLT, in non-sleep deprived, non-pathological persons. These are people who go to sleep easily, when given the opportunity, yet feel alert beforehand and have no problems in performing their daytime tasks. Should such people be called sleepy people or good sleepers?

Another way of looking at sleepiness is whether it reflects a state or trait. Sleepiness following sleep deprivation could be an example of state-induced sleepiness while the short SL of our non sleep-deprived, non-clinical subjects could be an example of a trait. It is less clear whether the sleepiness seen in narcoleptics and sleep apneics would be called state or trait. One could argue that in the early morning, the significant correlations in the present study reflected a post awakening state and as the day progressed other factors relating to alertness became important. Subjective estimates of sleepiness would be expected to be more sensitive to the daytime activities and changes in motivation than objective measures of sleep tendency. Seidel et al (13), in discussing their findings of a significant negative relationship between nocturnal sleep efficiency and MSLT, raised the possibility that sleep tendency may have both state and trait aspects. A recent report from the Henry Ford Hospital group (24) reported a .97 correlation between the average of four MSLTs recorded over a 4-14 months period. Even when the mean of two MSLTs recorded over the same period were examined, the test-retest correlations was .65 for morning tests and .79 for afternoon tests. Even with an N of 14 healthy subjects, these correlators were significant and the MSLT was more reliable over time than many well accepted behavioral trials.

The questions of whether there are one or more types of sleepiness and whether they reflect a state or a trait require further data and consideration. While we may not be ready to paraphrase a frequent statement in the

field of IQ testing to wit, "Sleepiness is what the test measures," our results plus those from other recent studies suggest that all measures of sleepiness are not necessarily measuring the same thing, and further, the relationship among them depends upon subject state and time of day.

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